

# **KNUCKLE BOOM FOR REACHING AND PULLING AND HYDRAULIC CIRCUITS THEREFOR**

## **BACKGROUND OF THE INVENTION**

### **Field of the Invention**

**[0001]** This invention relates to achieving more energy-efficient horizontal motion of a two-member knuckle boom, especially but not necessarily those which carry a tree-handling tool at the distal end thereof. The term "tree-handling tool" throughout this specification is intended to encompass, for example, tree felling; tree limbing heads; tree processing heads; wood-handling grapples for piling or loading trees or logs; and other such tools in the tree-harvesting industry.

### **Description of the Prior Art**

**[0002]** A typical two-member knuckle boom comprises a hoist boom having a proximal end pivoted to the machine base, and a stick boom having a proximal end pivoted to the distal end of the hoist boom. In the tree-harvesting industry, a tree-handling tool such as grapple tongs would be mounted on the distal end of the stick boom. A hoist cylinder is mounted between the machine base and the hoist boom, and a stick cylinder is mounted between the hoist boom and the stick boom.

**[0003]** The invention expands on the concepts described and claimed in Canadian patent no. 2,317,670, granted July 16, 2002, and in corresponding United States patent no. 6,443,196, granted September 3, 2002 (hereinafter referred to as "the prior Kurelek patents"). The prior Kurelek patents explained the concept of a hydraulic circuit for a knuckle boom which provides connecting hydraulic lines between the working ends of the hoist and stick cylinders providing an oil flow so as to enable shunting of hydraulic oil between the cylinder working ends. When these cylinders are alternately extending and contracting during reaching actions with the tool carrying knuckle boom, such as is always a part of tree harvesting, the circuit in that invention shunts load supporting hydraulic oil between the cylinders rather than dumping it to tank as with previous conventional circuits. This has resulted in reduced working horsepower, i.e. fuel used and heat generation, and the ability of the operator to do reaching and tucking by operating just one lever, while continuing to do lifting and lowering with the other. This is explained in detail in the prior Kurelek patents.

**[0004]** In the prior Kurelek patents, there is no direct control of the shunting of hydraulic oil, for example via a valve or pump. Instead, the "reach" movement of the boom (i.e. generally horizontal extension or retraction) is controlled by an additional hydraulic cylinder, acting as a "reach" cylinder, mounted between the hoist and stick booms. In one sense, the reach cylinder in effect controls or constrains the shunting of oil between the working ends, since the reach cylinder determines the relative positions of the hoist and stick cylinders. The reach cylinder operates one of the knuckle boom angles, usually working alongside the stick cylinder, and causes the load supporting oil to flow back and forth between the hoist and stick cylinders. In practice, tree harvesting machines with the concepts of the prior Kurelek patents do function with benefits as described, and have already become well-accepted by users.

**[0005]** The reach cylinder does not normally do major load supporting work but is required to provide the horizontal push and pull forces at the tool. Thus when as described in the prior Kurelek patents, the reach cylinder is located beneath the boom assembly, any push forces needed at the tool when reaching in an outward direction is obtained by pressurizing its base end. Since the base end area of typical modern logging machine cylinders is always about twice their rod end areas this is good for operations where the major knuckle boom function is to intermittently push hard on something under good speed control while reaching out, and to return quickly at light load while tucking back in.

**[0006]** Fig. 1 (prior art) is an example of such a prior invention case. The tree butt is gripped in a holder while the knuckle boom is reaching out to forcefully shear off limbs from the tree bole. After going through one of several options in bucking and placing the limbed tree part the boom must grasp and advance the next length of unlimbed tree so that it can be gripped by the holder for the next limbing stroke. Advancing the unlimbed tree with reach-in as it slides on the ground is usually much easier than it is to remove limbs on the stroke out, so the reach cylinder configuration and location in the prior Kurelek patents is good (for push type limbing).

**[0007]** The cylinder actions, hydraulic oil flows and operator controls, including the limbing-head-to-tree alignment, are taught in the prior Kurelek patents.

**[0008]** However, it has been realized by the inventor that there are applications of the efficient reach principle that would rather have the powerful steady stroke direction be when tucking in, rather than when reaching out.

**[0009]** Fig. 2 (prior art) depicts a logging operation that is often used in tree harvesting. Another illustration can be seen in Hamby, US patent no. 4,899,794, Fig. 1. In this case the knuckle boom machine is basically a loader and has a grapple as

the tool at the end of the stick. When limbing is wanted the loader at near full reach inserts the tree into a stationary limbing head and pulls it towards itself. Limbs are thus removed by a combined action of the conventional knuckle boom and swinging of the upper, as hydraulic oil is typically wastefully pumped into the base of the hoist cylinder and into the rod end of the stick cylinder. Davidson US patent no. 5,406,997 Fig. 1 also shows a loader doing "pull-through" limbing apparently with swing action. It is obvious though that if only swinging is used there is much tail sweep of the tree so reaching in and out is usually also used. After disposing of the limbed and bucked log the grapple must race out empty, but still wastefully, to grasp the butt of the next bole to be limbed.

**[0010]** If the tool being used on the knuckle boom end is one that severs the tree off the stump at an extended reach then sometimes it is wanted (e.g. for processing) to forcefully drag the tree in closer to the machine against the resistance of ground friction or incidental limb contacts. The operator can well give up reach force in the extending direction when the empty head is carried above the ground and avoiding other tree stems, and instead get more pulling force.

**[0011]** In converting a knuckle boom to be more efficient according to the prior Kurelek patents we do achieve the efficient reach objective. Pressurized oil is exchanged between the stick and hoist cylinders during pulling in and reaching out. But the slower, higher force action of the extending reach cylinder would occur when going back with empty tongs to get the next bole and not when hard pulling might be wanted to remove limbs or extract an entangled felled tree. The quicker less forceful action of the rod end area would attempt to do the limbing (pulling) stroke. The operator would appreciate the ease of one hand operation and the generally faster reach speeds but unless major changes in pressures and cylinder sizes were made he would probably wish for more pulling force.

#### **SUMMARY OF THE INVENTION**

**[0012]** It is an objective of this invention to improve the application of "efficient reach" to the above-described type of operation. Fig. 4 shows that instead of locating the reach cylinder underneath the booms in the common tree working style we can separate it from the stick cylinder and place it above the booms. In this new position the reach cylinder is still hydraulically connected as in the prior Kurelek patents. The stick cylinder of this new invention remains in the same beneath-the-boom position as in the prior Kurelek patents and it is still connected to the hoist cylinder in the same way and is proportioned in size to the hoist cylinder in the same way. But in

Fig. 4 it can be seen that oil applied to the more forceful base end of the reach cylinder will cause the knuckle boom to pull in, which is wanted. The same oil applied to the weaker rod end of the reach cylinder will now cause the stick boom tip to reach out at twice the speed, which is also wanted.

**[0013]** The idea to change the reach cylinder installation to suit a particular knuckle boom job is also useful in some other cases. Fig. 5 shows that when Kurelek's efficient reach is used on a grade leveling knuckle boom it too needs to have the reach cylinder on top so that its powerful push direction is used to cut the soil with the bucket lip. The operation of the sender and tilt cylinders shown in Fig. 5 is similar to that taught in the prior Kurelek patents where they are used to keep the felling head near vertical and the saw near horizontal during reach.

**[0014]** Fig. 6 deals with the case where a higher force is not needed in either direction, and high speed can be used in both directions. The reach cylinder has a rod at each end so that the same net piston area works in each direction. Such a device would work whether the reach cylinder was on top or underneath the boom but obviously it is easier to allow space for the base end protruding rod if on top. It is also possible to make the two rods of different diameters so that some variation from 1 to 1 in speeds and forces is obtained.

**[0015]** Fig. 7 illustrates what can be done if high limbing forces will happen in both directions e.g. if the tree is both pushed and pulled through a bi-directional head to remove particularly tenacious or heavy branches. There are two reach cylinders, one below and one above the boom, and if standard diameters are used the limbing forces available at similar knuckle positions will always be at least 50% higher than the maximum in Fig. 4.

**[0016]** Further details of the invention will be described or will become apparent in the course of the following detailed description.

#### **DESCRIPTION OF THE DRAWINGS**

**[0017]** The invention will now be described with reference to these accompanying drawings:

Fig. 1 (prior art) is a side elevation view showing how portions of the prior Kurelek patents are useful for tree limbing where the knuckle boom pushes a limbing head along the tree to shear off limbs.

Fig. 2 (prior art) is a side elevation view showing typical prior art knuckle boom limbing of trees where the knuckle boom pulls the tree through a fixed limbing head to shear off limbs.

Fig. 3 is a view showing how portions of the prior Kurelek patents are useful for tree limbing where the knuckle boom pulls the tree through a limbing head with efficient action but without a high available force.

Fig. 3B shows details of the hydraulic connections used in Fig. 3.

Fig. 4 is a view showing how this present invention is useful for tree limbing where the knuckle boom pulls the tree through a limbing head to shear off limbs with an efficient action and a high available force.

Fig. 4B shows details of the hydraulic connections used in Fig. 4.

Fig. 5 shows how this present invention is useful for leveling and smoothening earth materials with a grading bucket.

Fig. 6 is a view showing how this present invention is useful for slashing trees into logs by utilizing equal high boom tip speeds in both reach out and tuck in directions.

Fig. 6B shows details of the hydraulic connections used in Fig. 6.

Fig. 7 is a view showing how this present invention is useful for tree limbing where the knuckle boom both pushes and pulls to shear off very difficult limbs.

Fig. 7B shows details of the hydraulic connections used in Fig. 7.

#### **DETAILED DESCRIPTION OF THE INVENTION**

[0018] Fig. 1 (prior art) is pertinent to this limbing improvement invention because it illustrates a limbing operation method already possible using the prior Kurelek patents to get fast, efficient and forceful tree handling and limb removal. The knuckle boom is mounted on a carrier 3 which also has a tree butt holder 88 into which the

tree **82** is inserted by using the limbing head **81** and the knuckle boom loader comprised of hoist boom **6** and the stick boom **7** as shown in dotted outline. Then by operating the reach cylinder **16** and relying on hoist cylinder **10** and stick cylinder **11** to work as taught in the prior Kurelek patents limbs are sheared off the tree bole as the limbing head reaches out. Methods of closing the arms of the head on the tree as the bole size tapers are well known in the industry. Aligning the axis of the limbing head with the tree during the reach stroke is done by employing sender cylinder **17** and tilt cylinder **14** as also taught in the prior Kurelek patents. It is obvious that the limbing head and its controls must be designed primarily for removing branches cleanly and that usefulness of the carrier and knuckle boom for doing other common loader work would be reduced. Hence the industry preference for the limbing method of Fig. 2.

**[0019]** Fig. 2 (prior art) shows the common prior art in the industry for using an almost fully capable loader machine to also do pull-type limbing. The carrier **3** in this drawing has a conventional prior art knuckle boom comprising of hoist boom **6**, stick boom **7**, hoist cylinder **10**, stick cylinder **11** and a grapple **18**. Beside the loader there is a limber chassis **83** on which is mounted a limbing head **81**. The loader grapple is used to place the tree bole butt in the limbing head at position **87** and with the limber arms closed on it the loader pulls the tree, using reach tuck and some swing to remove limbs. The saw **80** can be used to buck off a log, which can be piled or loaded before reaching out to position **87** again for another limbing pull. Although this is a practical way to use a conventional loader it still retains the faults which the prior Kurelek patents avoided, namely the operator must use two levers to do reach, unnecessary oil heat is generated, fuel and power is wasted and the reach is not fast. Before examining how the present new invention allows the application of those benefits to this pull type of loader limbing it would be helpful to study the following description of those previous teachings with reference to Figs. 3 and 3B.

**[0020]** Figs. 3 and 3B show the portions of the embodiment of the prior Kurelek patents that are pertinent to the new invention, for pull-type loader limbing. There is an upper machine **3**, a machine base **1** supported above suitable tracks or wheels **2**. A diesel engine **4** is cantilevered on the back of the machine base. The knuckle boom assembly comprises a hoist boom **6**, and a stick boom **7**. The hoist boom is pivotally mounted relative to the machine base at a hoist-base pivot pin **8** on a mounting bracket **9** secured to the machine base. The stick boom is pivotally connected to the distal end of the hoist boom at a hoist-stick pivot pin **15**. The hoist boom is actuated by at least one hydraulic hoist cylinder **10** connected between the machine base and the hoist boom, at an effective angle relative to the hoist boom.

The stick boom is actuated by at least one stick cylinder **11** connected between the hoist boom and the stick boom, at an effective angle relative to the stick boom. A reach cylinder **16** is also connected between the hoist boom and the stick boom, at an effective angle relative to the stick boom. A tool, such as a tree grapple, is carried at **13** at the distal end of the stick boom.

**[0021]** The simplified schematic superimposed on Fig. 3B shows how the hydraulic connections are made to reduce reach energy consumption with an embodiment of the prior Kurelek patents. The lift directional control valve **27** is controlled by the operator with lever **26**. Conduits **108** and **114** connect the base end ports of both the hoist cylinder and the stick cylinder to one of the work ports of valve **27**. Conduits **107** and **113** connect the rod end ports of both the hoist cylinder and the stick cylinder to the other work port of valve **27**. Conduit **114** in effect unites the base end volume of the hoist cylinder **10** with the base end volume of the stick cylinder **11**. That is, the hoist cylinder and stick cylinder base ends are piped together and to a valve work port with hydraulic conduit, so that they share a common load-supporting pressurized volume or "slug" of oil behind their pistons.

**[0022]** A reach (directional) control valve **29** has its work ports connected by means of conduits **109** and **110** to the two ports of the reach cylinder so that the operator can stroke it with lever **28**, getting oil from pump **30**. As the reach cylinder is stroked, its mechanical connection with the stick cylinder lugs forces the stick cylinder to stroke as well. When thus forced to stroke, the stick cylinder must exchange oil with the hoist cylinder via lines **113** and **114** and causes it to stroke and raise or lower the hoist boom. According to the prior Kurelek patents the cylinder installation geometry is such that the oil exchanged by the hoist cylinder with the stick cylinder through the conduit **114** is the correct amount to maintain the stick boom point **13** at a nearly constant height as the reach cylinder is stroked.

**[0023]** When the lift valve is operated alone, i.e. while leaving the reach valve not shifted, the reach cylinder will lock the stick cylinder with it, so oil flowing in line **108** can only cause the hoist cylinder to stroke and so raise or lower the tool about pivot pin **8**.

**[0024]** Hence the prior Kurelek patents have established an art in hydraulic circuits for knuckle booms that saves energy by transferring load supporting pressurized oil between hoist and stick cylinders during reaching and at the same time gives the operator single lever reach control. The already pressurized oil is caused to flow directly between cylinders by adding a reach cylinder to the knuckle boom.

**[0025]** Fig. 3 shows how this is applied to a limbing head **81** mounted on a chassis **83**. A grapple **18** is moved with reach action to the **87** location and then back with tuck to pull lengths of tree **82** through the limber and buck them off with the saw **80**. Thus the loader in Fig. 3 fits into the job exactly the same as the loader of Fig. 2 but being of the energy efficient type is an improvement over the prior art of Fig. 2. However because the smaller rod end area of the reach cylinder is used to pull the tree in the direction of limb removal and the larger base end area is used to go back empty there is an opportunity for further improvement.

**[0026]** In the present invention, as illustrated in Figs. 4 and 4B, there is an additional performance improvement in that the limbing force available with given equipment size is doubled and the empty return speed can also be doubled. Comparing Fig. 4B with Fig. 3B the significant difference that causes the improvement is that the reach cylinder **16** has been moved from beneath the booms where it was pinned to the hoist boom at pin **69** and to the stick boom at pin **68** to above the hoist boom where it is pinned at its base end to the hoist boom with pin **61** and to an extension crank of the stick boom with pin **65**. In this position of the reach cylinder, extending it to cause pull at the grapple **18** is done by applying oil pressure to its base end which has approximately twice the area of the rod end used to pull the tree through the limber in Figs. 3 and 3B.

**[0027]** Fig. 5 is another case, where the reach cylinder of the prior Kurelek patents is better to be located on top of the boom. All the items used to explain its operation are the same as in Fig. 4 except there is a scraper bucket **91** instead of a grapple. Also, similar to the limbing head **81** in Fig. 1, the bucket attitude is shown controlled by a sender cylinder **17** and a tilt cylinder **14**. Usually it is wanted to cut into the ground with the bucket lip while tucking towards the carrier. Since efficient reach art can be set up to accurately scrape a level grade it is particularly useful to have the extra pull force provided by the top located reach cylinder.

**[0028]** Fig. 6 is a further case where placing the reach cylinder above the boom yields an advantage. Fig. 6 is an illustration of a logging machine commonly called a slasher and its use in cutting long already limbed trees **85** into logs and piling or loading them. The loader knuckle boom with hoist boom **6** and stick boom **70** and grapple **18** advances trees from position at **87** to a butt plate **92** without the resistance of limb removal. After being slashed with the saw **86** the logs are piled or loaded on a truck and the knuckle boom reaches out empty to grapple more of the trees. Thus since neither direction of reach needs a large force and both directions can benefit from greater speed it is a useful invention to install the double rod ended



cylinder **60** in the location above the boom. Hoist cylinder **10** and stick cylinder **11** are connected according to the prior Kurelek patents teachings.

**[0029]** In Fig. 6B it is seen that the effective net area for both force and speed on both sides of piston **64** is reduced by rods **62** and **63**. Rod diameters could be tailored to get precise speed ratio conditions. The pinning to the hoist boom at **71** must be constructed as a trunnion through which the rod **62** can pass. Whether oil is supplied from the pump **30** via valve **29** and conduit **109** or through conduit **110**, the force and speed available at boom point **13** will be the same. It can be visualized from the pictorial appearance of the boom structure at pin **69** on Fig. 3B that there would not easily be clearance for a double rod ended cylinder in the lower location. Having moved the reach cylinder to above the boom has made this improved slasher operation possible.

**[0030]** Fig. 7 illustrates the case where a limby tree **82** is inserted into a bi-directional limbing head **81** at some distance from its butt and then limbed by pushing and pulling with the knuckle boom. A high reach force might be needed in both directions and lower speeds would be accepted. It is a solution to arrange pinning for both a top mounted reach cylinder **60** and a beneath mounted reach cylinder **16**.

**[0031]** In Fig. 7B it is seen that the hoist cylinder **10** and the stick cylinder **11** are connected as per the prior Kurelek patents but that the two reach cylinders are connected so that in a given direction a base end of one works with the rod end of the other. Speeds and forces are approximately equal in both directions.